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# PRINCIPLES OF HORSE FEEDING.

BY

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## LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
*Washington, D. C., May 1, 1903.*

SIR: I have the honor to transmit herewith an article on horse feeding, prepared by C. F. Langworthy, of this Office, and recommend that it be published as a Farmers' Bulletin. The bulletin discusses the general principles of feeding, with especial reference to horses, and summarizes the results of recent experimental work, particularly that of American experiment stations, the material in its present form being very largely an abridgment of a more technical publication by the same author, issued as Bulletin No. 125 of the Office of Experiment Stations, entitled "A Digest of Recent Experiments on Horse Feeding."

Respectfully,

A. C. TRUE,
*Director.*

Hon. JAMES WILSON,
*Secretary of Agriculture.*

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# PRINCIPLES OF HORSE FEEDING.

## INTRODUCTION.

The scientific study of different problems connected with the feeding of farm animals has been followed for something over half a century. Some of the very early work was with horses, but more generally it was carried on with other domestic animals. Within the last few years this phase of the problem has received much more attention, and feeding tests, digestion experiments, and more complicated investigations have accumulated in considerable numbers. The bulk of this work has been carried on in France and Germany; a creditable amount, however, has been done in this country, notably by the agricultural experiment stations, and the results of these experiments and observations have been published from time to time, and are very useful. Mention must be made also of the work of practical feeders, which is of great value.

In the present bulletin the attempt is made to bring together some of the more important results and deductions which may be gathered from the American and foreign experimental work, especially that of recent years. It is not the purpose to provide practical feeders with directions for feeding according to a particular formula; indeed this is not necessary, if it were possible, for practical feeders to a great extent understand the needs of their horses and how to meet them. The object is rather to summarize matter which seems interesting and valuable, and which in many cases may give the reason for something of which the wisdom has long been recognized in practice.

The problem of horse feeding is one which each feeder solves more or less for himself, the opinion regarding what is and what is not satisfactory feed varying more or less with the time and place. Opinions may differ as to the value of this food or that, but it is evident that the actual food requirements of a horse performing a given amount of work can not vary as a result of a change of opinion on the feeder's part. With horses, as with all animals, including man, the real problem is to supply sufficient nutritive material for building and repairing the body and furnishing it with the energy necessary for performing work, whether it be that which goes on inside the body (the beating

of the heart, respiratory movements, etc.), or the work which is performed outside the body (hauling a load, etc.). The body temperature must also be maintained at the expense of the fuel ingredients, but whether material is burned in the body primarily for this purpose, or whether the necessary heat is a resultant of the internal muscular work, is not known with certainty.

The problem of successfully feeding horses differs somewhat from that encountered in feeding most domestic animals. Cattle, sheep, and pigs are fed to induce gains in weight, i. e., to fatten them, or in the case of milch cows to produce gains in the form of a body secretion (milk) rather than as fat in the body. In a similar way sheep are fed for the production of wool, and poultry for the production of eggs. Sometimes cattle are also fed as beasts of burden. Horses are fed almost universally as beasts of burden, whether the work consists in carrying a rider or drawing a load.

Mares with foal require food for the development of their young, and after birth the colt needs it for the growth and development of the body as well as for maintenance. Such demands for nutritive material are common to all classes of animals. Sometimes horses are fed to increase their weight; that is, to improve their condition. For instance, animals are often fattened by horse dealers before they are sold. However, generally speaking, the problem in horse feeding is to supply sufficient nutritive material for the production of the work required and at the same time to maintain the body weight. The almost universal experience of practical horse feeders, and the results of many carefully planned experiments, agree that there is no surer test of the fitness of any given ration than that it enables the horse fed to maintain a constant weight. If the animal loses weight it is evident that the ration is insufficient, while if gains in weight are made and the animal becomes fat it is evident that more feed is given than is necessary. Provided the horse is in good condition, it is seldom desirable to induce any considerable gain in weight. Reference is not made to the small daily fluctuations in weight, but to gains or losses which extend over a considerable period. The most satisfactory ration must necessarily be made up of materials which are wholesome and are relished by the horse. It should also be reasonable in cost. It must be abundant enough to meet all body requirements, but not so abundant that the horse lays on an undesirable amount of flesh.

## PRINCIPLES OF NUTRITION.

The foundation principles of nutrition are the same in the case of all animals, including man. A brief discussion of the properties of food and the general laws of nutrition follows.

The study of foods and feeding stuffs has shown that although they differ so much in texture and appearance they are in reality made up

of a small number of chemical constituents, namely, protein, fat, carbohydrates, and ash, together with a larger or smaller amount of water. The latter can be often seen, as in the juice of fresh plants. In dry hay no water or juice is visible. A small amount is, however, contained in minute particles in the plant tissues.

Protein is a name given to the total group of nitrogenous materials present. The group is made up mainly of the true proteids and albumens such as the gluten of wheat, and of nitrogenous materials such as amids, which are believed to have a lower feeding value than the albumens.

The group "fat" includes the true vegetable fats and oils, like the oil in cotton seed or corn, as well as vegetable wax, some chlorophyl (the green coloring matter in leaves, etc.), and other coloring matters; in brief, all the materials which are extracted by ether in the usual laboratory method of estimating fat. The name "ether extract" is often and quite properly applied to this group.

The group "carbohydrates" includes starches, sugars, crude fiber, cellulose, pentosans, and other bodies of a similar chemical structure. This group is usually subdivided, according to the analytical methods followed in estimating it, into "nitrogen-free extract" and "crude fiber;" the former subdivision including principally sugar, starches, and most of the pentosans, and the latter cellulose, lignin, and other woody substances which very largely make up the rigid structure of plants.

The group "mineral matter" includes the inorganic bodies present in the form of salts in the juices and tissue of the different feeding stuffs, the principal chemical elements found being sodium, potassium, calcium, chlorin, fluorin, phosphorus, and sulphur. The term "ash" is often and very appropriately used for this group, since the mineral matter represents the incombustible portion which remains when any given feeding stuff is burned.

The functions of food are (1) to supply material to build and repair the body, and (2) to yield energy. The chemical composition of a feeding stuff serves as a basis for judging of its value for building and repairing body tissue. Its value as a source of energy must, however, be learned in another way. The most usual way of measuring energy is in terms of heat, the calorie being taken as a unit. This is the amount of heat which would raise the temperature of 1 kilogram of water 1° C., or 1 pound of water 4° F. Instead of this the unit of mechanical energy, the foot-ton (the force which would lift 1 ton 1 foot), may be used, but it is not as convenient. One calorie corresponds very nearly to 1.54 foot-tons.

The fuel value of any food is equal to its heat of combustion less the energy of the excretory products derived from it, and may be learned by taking into account the chemical composition of the food

or feeding stuff, the proportions of the nutrients actually digested and oxidized in the body, and the proportion of the whole latent energy of each which becomes active and useful to the body for warmth and work. However, the fuel value may be and often is calculated from the composition of the food material supplied, on the assumption that 1 gram of protein furnishes 4.1 calories, 1 gram fat 9.3 calories, and 1 gram carbohydrates 4.1 calories, or 1 pound protein 1,860 calories, 1 pound fat 4,220 calories, and 1 pound carbohydrates 1,860 calories.

The relation between the quantities of nitrogenous and nitrogen-free nutrients in the ration is called the nutritive or nutrient ratio. In calculating this ratio 1 pound of fat is taken as equivalent to 2.25 pounds of carbohydrates—this being approximately the ratio of their fuel values—so that the nutritive ratio is actually that of the protein to the carbohydrates plus 2.25 times the fat.

All the organs and tissues of the body contain nitrogen. Protein is the only nutrient which supplies this element, and is therefore essential for building and repairing body tissues. The other elements required, namely, carbon, oxygen, and hydrogen, may be supplied theoretically by protein, fat, or carbohydrates; but a well-balanced diet or ration contains all the nutrients in proper proportion. Protein, fat, and carbohydrates may be burned with the formation of carbon dioxid and water, and therefore all may serve as sources of energy.

The mineral matter in food is required for a number of different purposes, a considerable amount being needed for the formation of the skeleton. Some is also present in the organs and tissues. It can not, however, be regarded as a source of energy, according to commonly accepted theories, since it can not be burned with the formation of carbon dioxid and water. The water present in food is not a nutrient in the sense that it serves for building tissue or yielding energy, but it is essential, serving to carry the food in the digestive processes, to dilute the blood, and for many other physiological purposes. The oxygen of the air is required by all living animals for the combustion, or oxidation, of the fuel constituents of food.

When foods are burned in the body, i. e., oxidized, they give up the latent energy present in them. In determining the fuel value of protein, due allowance is made for the fact that combustion is not as complete in the body as in a furnace.

The body is often likened to a machine, but it differs from one in a number of important ways; for instance, it is itself built up of the same materials which it utilizes as fuel, and further, if an excess of fuel, i. e., food, is supplied, it may be stored as a reserve material for future use, generally in the form of fat or glycogen, a sugar-like body.

The amount of work performed by a horse, for convenience in measurement, may be resolved into several factors, as follows: (1) The energy expended in chewing, swallowing, and digesting food, keeping

up the beating of the heart, circulation of the blood, respiratory movements, and other vital processes; (2) the energy which is expended in moving the body, walking, trotting, etc., which is usually spoken of as energy required for forward progression; and (3) the energy which is expended in carrying a rider, as in the case of a saddle horse, or drawing a load, as in the case of a draft animal or carriage horse.

The character of the road, whether level or up or down hill, is an important factor in determining the amount of work. It is evident that more energy is required to lift the body at each step and move it forward when climbing an incline than when walking on a level. In the same way, when a load is drawn uphill it must be raised as well as drawn forward.

Work may be measured as foot-pounds or foot-tons, or by any other convenient unit. A foot-pound is the amount of energy expended in raising 1 pound 1 foot; a foot-ton, that expended in raising 1 ton 1 foot; a commonly used unit of force is the "ton power," equivalent to 550 foot-pounds per second. Work may also be measured in terms of heat, i, e., calories. This is especially convenient in discussing problems of nutrition, since the heat of combustion is one of the factors usually determined or calculated when foods are analyzed; and furthermore, the feeding standards which have been proposed for horses and other farm animals show the requirements per day in terms of nutrients and energy. One calorie corresponds, as stated above, very nearly to 1.54 foot-tons.

## COMPOSITION OF FEEDING STUFFS.

The feeding stuffs of most importance for horses are cereal grains, such as oats and corn, either ground or unground; leguminous seeds, as beans and peas; cakes, and other commercial by-products, as oil-cake, gluten feed, and so on; fodder crops, green or cured; and different roots, tubers, and green vegetables. In quite recent times cane molasses, beet molasses, and other beet-sugar by-products have assumed more or less importance in this connection. The composition of a number of these different feeding stuffs may be seen by reference to Table 1, which shows the average composition as determined by analysis, and when possible the digestible nutrients furnished by each 100 pounds of the feeding stuffs, the latter data having been calculated by the aid of figures obtained in digestion experiments with horses. In a number of cases such calculations have not been made, for the reason that experiments showing the digestibility of the feeding stuffs have not been found, nor were results of experiments made with similar feeding stuffs available. The comparatively large number of feeding stuffs of which the digestibility has not been determined indicates one of the lines of work which might be profitably followed.

TABLE 1.—*Average composition of a number of feeding stuffs.*

| Kind of food material. | Percentage composition. Water. | Protein. | Fat. | Nitrogen-free extract. | Crude fiber. | Ash. | Digestible materials in 100 pounds. Protein. | Fat. | Nitrogen-free extract. | Crude fiber. | Energy in 100 lbs. digestible nutrients. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| GREEN FODDER. | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Calories.* |
| Corn fodder | 79.3 | 1.8 | 0.5 | 12.2 | 5.0 | 1.2 | ...... | ...... | ...... | ...... | ...... |
| Corn leaves and husks | 66.2 | 2.1 | 1.1 | 19.0 | 8.7 | 2.9 | ...... | ...... | ...... | ...... | ...... |
| Cornstalks stripped | 76.1 | .5 | .5 | 14.9 | 7.3 | .7 | ...... | ...... | ...... | ...... | ...... |
| Kafir corn | 73.0 | 2.3 | .7 | 15.1 | 6.9 | 2.0 | ...... | ...... | ...... | ...... | ...... |
| Rye fodder | 76.6 | 2.6 | .6 | 6.8 | 11.6 | 1.8 | ...... | ...... | ...... | ...... | ...... |
| Oat fodder | 62.2 | 3.4 | 1.4 | 19.3 | 11.2 | 2.5 | ...... | ...... | ...... | ...... | ...... |
| Wheat fodder | 77.3 | 2.3 | .7 | 12.0 | 5.9 | 1.8 | ...... | ...... | ...... | ...... | ...... |
| Orchard grass | 73.0 | 2.6 | .9 | 13.3 | 8.2 | 2.0 | ...... | ...... | ...... | ...... | ...... |
| Meadow fescue | 69.9 | 2.4 | .8 | 14.3 | 10.8 | 1.8 | ...... | ...... | ...... | ...... | ...... |
| Timothy | 61.6 | 3.1 | 1.2 | 20.2 | 11.8 | 2.1 | ...... | ...... | ...... | ...... | ...... |
| Kentucky blue grass | 65.1 | 4.1 | 1.3 | 17.6 | 9.1 | 2.8 | ...... | ...... | ...... | ...... | ...... |
| Red clover | 70.8 | 4.4 | 1.1 | 13.5 | 8.1 | 2.1 | 3.44 | ...... | 10.94 | 3.79 | 33,796 |
| Alsike clover[a] | 74.8 | 3.9 | .9 | 11.0 | 7.4 | 2.0 | 3.05 | ...... | 8.91 | 3.46 | 28,681 |
| Alfalfa | 71.8 | 4.8 | 1.0 | 12.3 | 7.4 | 2.7 | 3.75 | ...... | 9.96 | 3.46 | 31,936 |
| Cowpea | 83.6 | 2.4 | .4 | 7.1 | 4.8 | 1.7 | ...... | ...... | ...... | ...... | ...... |
| Soy bean | 75.1 | 4.0 | 1.0 | 10.6 | 6.7 | 2.6 | ...... | ...... | ...... | ...... | ...... |
| SILAGE. | | | | | | | | | | | |
| Corn silage | 74.4 | 2.2 | 1.1 | 15.0 | 5.8 | 1.5 | ...... | ...... | ...... | ...... | ...... |
| Sorghum silage | 76.1 | .8 | .3 | 15.3 | 6.4 | 1.1 | ...... | ...... | ...... | ...... | ...... |
| Red-clover silage | 72.0 | 4.2 | 1.2 | 11.6 | 8.4 | 2.6 | ...... | ...... | ...... | ...... | ...... |
| Cowpea-vine silage | 79.3 | 2.7 | 1.5 | 7.6 | 6.0 | 2.9 | ...... | ...... | ...... | ...... | ...... |
| HAY AND DRY COARSE FODDER. | | | | | | | | | | | |
| Corn fodder, field cured | 42.2 | 4.5 | 1.6 | 34.7 | 14.3 | 2.7 | ...... | ...... | ...... | ...... | ...... |
| Corn leaves, field cured | 30.0 | 6.0 | 1.4 | 35.7 | 21.4 | 5.5 | ...... | ...... | ...... | ...... | ...... |
| Corn husks, field cured | 50.9 | 2.5 | .7 | 28.3 | 15.8 | 1.8 | ...... | ...... | ...... | ...... | ...... |
| Cornstalks, field cured | 68.4 | 1.9 | .5 | 17.0 | 11.0 | 1.2 | ...... | ...... | ...... | ...... | ...... |
| Corn stover, field cured | 40.5 | 3.8 | 1.1 | 31.5 | 19.7 | 3.4 | ...... | ...... | ...... | ...... | ...... |
| Kafir-corn stover, field cured | 19.2 | 4.8 | 1.6 | 39.6 | 26.8 | 8.0 | ...... | ...... | ...... | ...... | ...... |
| Barley hay | 10.6 | 9.3 | 2.5 | 48.7 | 23.6 | 5.3 | ...... | ...... | ...... | ...... | ...... |
| Oat hay | 16.0 | 7.4 | 2.7 | 40.6 | 27.2 | 6.1 | ...... | ...... | ...... | ...... | ...... |
| Wheat hay | 8.8 | 6.0 | 1.8 | 55.3 | 22.5 | 5.6 | ...... | ...... | ...... | ...... | ...... |
| Redtop | 8.9 | 7.9 | 1.9 | 47.5 | 28.6 | 5.2 | 4.51 | 0.39 | 26.93 | 11.35 | 81,234 |
| Orchard grass[b] | 9.9 | 8.1 | 2.6 | 41.0 | 32.4 | 6.0 | 4.62 | .54 | 23.25 | 12.86 | 78,036 |
| Timothy | 13.2 | 5.9 | 2.5 | 45.0 | 29.0 | 4.4 | 1.25 | 1.18 | 21.29 | 12.35 | 69,873 |
| Kentucky blue grass[b] | 21.2 | 7.8 | 3.9 | 37.8 | 23.0 | 6.3 | 4.45 | .81 | 21.43 | 9.13 | 68,536 |
| Hungarian grass[b] | 7.7 | 7.5 | 2.1 | 49.0 | 27.7 | 6.0 | 4.28 | .43 | 27.78 | 11.00 | 81,905 |
| Meadow fescue[b] | 20.0 | 7.0 | 2.7 | 38.4 | 25.0 | 6.9 | 4.00 | .56 | 21.77 | 10.28 | 69,415 |
| Italian rye grass[b] | 8.5 | 7.5 | 1.7 | 44.9 | 30.5 | 6.9 | 4.28 | .35 | 25.51 | 12.11 | 79,410 |
| Mixed grasses[b] | 15.3 | 7.4 | 2.5 | 42.1 | 27.2 | 5.5 | 4.23 | .52 | 23.87 | 10.80 | 74,554 |
| Rowen (mixed)[b] | 16.6 | 11.6 | 3.1 | 39.4 | 22.5 | 6.8 | 6.62 | .64 | 22.34 | 8.93 | 73,175 |
| Mixed grasses and clovers[b] | 12.9 | 10.1 | 2.6 | 41.3 | 27.6 | 5.5 | 5.77 | .54 | 23.42 | 10.96 | 76,957 |
| Redclover | 15.3 | 12.3 | 3.3 | 38.1 | 24.8 | 6.2 | 6.85 | .95 | 24.19 | 9.27 | 78,984 |
| Alsike clover[c] | 9.7 | 12.8 | 2.9 | 40.7 | 25.6 | 8.3 | 7.13 | .83 | 25.84 | 9.57 | 82,630 |
| White clover[c] | 9.7 | 15.7 | 2.9 | 39.3 | 24.1 | 8.3 | 8.74 | .83 | 24.96 | 9.01 | 82,942 |
| Alfalfa | 8.4 | 14.3 | 2.2 | 42.7 | 25.0 | 7.4 | 10.67 | .42 | 29.98 | 9.75 | 95,520 |
| Cowpea | 10.7 | 16.6 | 2.9 | 42.2 | 20.1 | 7.5 | ...... | ...... | ...... | ...... | ...... |
| Wheat straw | 9.6 | 3.4 | 1.3 | 43.4 | 38.1 | 4.2 | .94 | .85 | 12.20 | 6.74 | 40,544 |
| Rye straw[d] | 7.1 | 3.0 | 1.2 | 46.6 | 38.9 | 3.2 | .83 | .79 | 13.10 | 6.89 | 42,020 |
| Oat straw[d] | 9.2 | 4.0 | 2.3 | 42.4 | 37.0 | 5.1 | 1.11 | 1.51 | 11.91 | 6.55 | 42,770 |
| Buckwheat straw | 9.9 | 5.2 | 1.3 | 35.1 | 43.0 | 5.5 | ...... | ...... | ...... | ...... | ...... |
| ROOTS AND TUBERS. | | | | | | | | | | | |
| Potatoes | 78.9 | 2.1 | .1 | 17.3 | .6 | 1.0 | 1.85 | ...... | 17.20 | .05 | 35,525 |
| Carrots | 88.6 | 1.1 | .4 | 7.6 | 1.3 | 1.0 | 1.09 | ...... | 7.13 | ...... | 15,290 |
| GRAINS AND OTHER SEEDS. | | | | | | | | | | | |
| Corn, dent | 10.6 | 10.3 | 5.0 | 70.4 | 2.2 | 1.5 | 5.95 | 2.39 | 62.09 | ...... | 136,636 |
| Corn, flint | 11.3 | 10.5 | 5.0 | 70.1 | 1.7 | 1.4 | 6.07 | 2.39 | 61.83 | ...... | 136,376 |
| Corn, all varieties | 10.9 | 10.5 | 5.4 | 69.6 | 2.1 | 1.5 | 6.07 | 2.58 | 61.39 | ...... | 136,363 |

[a] Digestibility calculated from values obtained with green alfalfa.
[b] Digestibility calculated from values obtained with meadow hay.
[c] Digestibility calculated from values obtained with red-clover hay.
[d] Digestibility calculated from values obtained with wheat straw.

TABLE 1.—*Average composition of a number of feeding stuffs*—Continued.

| Kind of food material. | Percentage composition. | | | | | | Digestible materials in 100 pounds. | | | | Energy in 100 lbs. digestible nutrients. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Water. | Protein. | Fat. | Nitrogen-free extract. | Crude fiber. | Ash. | Protein. | Fat. | Nitrogen-free extract. | Crude fiber. | |
| GRAINS AND OTHER SEEDS—continued. | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Calories.* |
| Kafir corn | 12.5 | 10.9 | 2.9 | 70.5 | 1.9 | 1.3 | | | | | |
| Chicken corn | 14.8 | 10.6 | 2.6 | 58.8 | 8.7 | 4.5 | | | | | |
| Barley | 10.9 | 12.4 | 1.8 | 69.8 | 2.7 | 2.4 | | | | | |
| Oats | 11.0 | 11.8 | 5.0 | 59.7 | 9.5 | 3.0 | 9.39 | 3.60 | 45.25 | 2.82 | 122,062 |
| Rye | 11.6 | 10.6 | 1.7 | 72.5 | 1.7 | 1.9 | 8.51 | .72 | 63.29 | 1.70 | 139,747 |
| Wheat | 10.5 | 11.9 | 2.1 | 71.9 | 1.8 | 1.8 | | | | | |
| Cotton seed, whole | 9.1 | 19.6 | 20.1 | 28.3 | 18.9 | 4.0 | | | | | |
| Cowpea | 11.9 | 23.5 | 1.7 | 55.7 | 3.8 | 3.4 | | | | | |
| MILL PRODUCTS. | | | | | | | | | | | |
| Corn meal | 15.0 | 9.2 | 3.8 | 68.9 | 1.9 | 1.4 | 6.99 | 2.55 | 64.70 | .38 | 144,454 |
| Oats, ground | 11.7 | 11.0 | 3.9 | 52.3 | 18.0 | 3.1 | 9.06 | 3.12 | 45.03 | 2.59 | 118,727 |
| Corn-and-cob meal | 15.1 | 8.5 | 3.5 | 64.8 | 6.6 | 1.5 | | | | | |
| Barley meal | 11.9 | 10.5 | 2.2 | 66.3 | 6.5 | 2.6 | | | | | |
| Pea meal | 10.5 | 20.2 | 1.2 | 51.1 | 14.4 | 2.6 | | | | | |
| Ground corn and oats (equal parts). | 11.9 | 9.6 | 4.4 | 71.9 | | 2.2 | | | | | |
| BY-PRODUCTS. | | | | | | | | | | | |
| Corncob | 10.7 | 2.4 | .5 | 54.9 | 30.1 | 1.4 | | | | | |
| Corn bran | 8.7 | 9.8 | 6.2 | 62.6 | 11.2 | 1.5 | | | | | |
| Gluten meal | 8.6 | 30.0 | 8.8 | 49.2 | 2.6 | .8 | | | | | |
| Gluten feed | 7.8 | 23.4 | 8.3 | 53.2 | 6.2 | 1.1 | | | | | |
| Oat feed | 7.7 | 16.0 | 7.1 | 59.4 | 6.1 | 3.7 | | | | | |
| Brewers' grains, wet | 75.7 | 5.4 | 1.6 | 12.5 | 3.8 | 1.0 | | | | | |
| Brewers' grains, dried | 8.0 | 24.1 | 6.7 | 44.8 | 13.0 | 3.4 | | | | | |
| Rye bran | 11.8 | 14.7 | 2.8 | 63.9 | 3.3 | 3.5 | | | | | |
| Wheat bran | 11.9 | 15.4 | 4.0 | 53.9 | 9.0 | 5.8 | | | | | |
| Wheat middlings | 12.1 | 15.6 | 4.0 | 60.4 | 4.6 | 3.3 | | | | | |
| Wheat shorts | 11.8 | 14.9 | 4.5 | 56.8 | 7.4 | 4.6 | | | | | |
| Cotton-seed meal | 8.2 | 42.3 | 13.1 | 23.6 | 5.6 | 7.2 | | | | | |
| Cotton-seed hulls | 11.1 | 4.2 | 2.2 | 33.4 | 46.3 | 2.8 | | | | | |
| Linseed meal, old process | 9.2 | 32.9 | 7.9 | 35.4 | 8.9 | 5.7 | | | | | |
| Linseed meal, new process | 9.9 | 35.9 | 3.0 | 36.8 | 8.8 | 5.6 | | | | | |
| Beet-sugar molasses | 25.7 | [a] 7.3 | | [b] 58.2 | | 8.8 | 7.3 | | 58.2 | | 259,182 |
| Cane-sugar molasses | 25.1 | [a] 2.4 | | [b] 69.3 | | 3.2 | 3.2 | | 69.3 | | 298,398 |

[a] Largely nonalbuminoid nitrogenous materials.
[b] Very largely sugars.

## COMPARATIVE VALUE OF FEEDING STUFFS.

### CEREAL GRAINS.

It will be seen that the cereal grains resemble one another quite closely in composition, being characterized by fairly low water content and a considerable amount of protein and nitrogen-free extract. Some crude fiber, derived from the outer or bran layer of the grain, is also present. The superiority of one grain over another, if it exists at all, must therefore depend, in large measure, on some factor other than composition. It has been urged by many that oats possess a peculiar stimulating body called "avenin," and are on this account superior to other grains for horses. Oats undoubtedly possess a flavor or some such characteristic which makes them a favorite food with horses, but the most careful chemical study has failed to reveal

any substance of the nature of the theoretical avenin. Recent experiments have shown that the fat of oats and oat straw is more thoroughly digested than that of other cereals. This is suggested as a possible explanation of the superior feeding value of oats.

It is believed by many that horses show more spirit when oats form part of the ration. Discussing this subject, Director W. A. Henry, of the Wisconsin Experiment Station, says:

Horses nurtured on oats show mettle which can not be reached by the use of any other feeding stuff. Then, too, there is no grain so safe for horse feeding, the animal rarely being seriously injured if by accident or otherwise the groom deals out an oversupply. This safety is due in no small measure to the presence of the oat hull, which causes a given weight of grain to possess considerable volume, because of which there is less liability of mistake in measuring out the ration; further, the digestive tract can not hold a quantity of oat grains sufficient to produce serious disorders. Unless the horse is hard pressed for time or has poor teeth oats should be fed in the whole condition. Musty oats should be avoided.

Horsemen generally agree that new oats should not be used, though Boussingault, conducting extensive experiments with army horses, arrived at the conclusion that new oats do not possess the injurious qualities attributed to them.

The grain most commonly substituted for oats in this country is Indian corn or maize. It is so commonly used, especially in the South and West, that it is difficult to realize the prejudice which has existed against it in other countries. It has been asserted that there are climatic and other conditions which render corn a suitable horse feed in America which do not exist elsewhere. This hardly seems reasonable, and has not been borne out by the numerous experiments undertaken in France, Germany, and other countries. Such experiments have demonstrated the value of corn and shown the truth of the opinions generally held in this country, namely, that it is a safe and satisfactory feeding stuff for horses.

Barley, rye, and wheat are sometimes fed to horses. Their resemblance to oats in composition will be seen by reference to the table. All these grains should be substituted on the basis of chemical composition, and not pound for pound. As would be expected, the ground grains differ little from the same varieties before grinding.

Bran, shorts, middlings, and other by-products vary in composition, but all have a low water content, while the crude fiber content is generally rather high. Their nutritive ingredients are principally protein and carbohydrates. The high crude fiber content is due to the fact that these products represent the outer layers of the grain, which are more hard and firm in structure than the interior portion, which consists quite largely of starch.

The total number of tests to compare different feeding stuffs for horses which have been undertaken by the agricultural experiment stations in the United States is not large compared with the tests made with other farm animals. The results obtained are, however, interesting.

The problem most often investigated has been the possibility of substituting other grains for oats wholly or in part in the ration of work horses without lowering their efficiency. In this connection the Maine Station studied the value of pea meal and middlings fed in the ratio of 1 part of the former to 2 parts of the latter and of mixed grains as compared with oats. The Utah Station compared corn and bran and shorts with oats; the North Dakota Station, bran and shorts, barley and bran, and mixed grains. As a whole these and similar tests offered practical demonstrations of the fact that oats could be replaced by other grains when circumstances warranted it.

At the New Hampshire Station the value of different grain mixtures for horses was studied with a view to learning how the cost of a ration could be diminished by lessening the amount of oats fed. The rations consisted of different mixtures of oats, bran, corn, gluten feed, linseed meal, and cotton-seed meal. Fairly good results were obtained with all the mixtures, that containing cotton-seed meal being least satisfactory, as it was not at first relished by the horses. The conclusion was reached that any mixed ration furnishing the desired nutrients at a reasonable price should be considered. A mixture of bran and corn 1:1 was regarded as a good substitute for corn and oats for work horses.

Tests carried on at the Utah Station have demonstrated the value of wheat for horses, a grain which sometimes has so low a market value that it may be profitably fed.

The North Dakota Station has carried on a number of tests with barley which furnish experimental evidence that this grain is a useful feed. When taxed to the limit by hard work it was found, in the experiments referred to, that the horses could not be supported upon barley quite as well as upon oats, and that it was worth slightly less per pound than oats with animals performing a medium amount of work. Mules did not take as kindly to barley as horses, and dainty horses would not eat it quite as readily as oats. On the Pacific coast barley is extensively grown as a horse feed, and its use for this purpose is old in other countries. Elsewhere barley is not extensively used as a feed in the United States, doubtless owing to the fact that it is in such demand for brewing purposes that it is usually high in price. Wherever it is grown, however, it is frequently possible to secure at a low cost grain which is off color owing to rain or fog during harvest, and which, for this or some other reason, is unfit for brewing, but valuable as feed.

Barley may be fed whole to horses having good teeth and not required to do severe work. Since ground barley, like wheat, forms a pasty mass when mixed with saliva, it is regarded as more satisfactory to crush than to grind it, if for any reason it is considered undesirable to feed the grain whole.

A test at the North Dakota Station with malted barley indicated that this is not an economical feed for work horses.

Kafir corn is a grain which is assuming more and more importance in the semiarid regions of the United States and is replacing corn in many ways. The Oklahoma Station has tested its value as a horse feed and regards it as healthful, palatable, and nutritious with a feeding value somewhat less than corn. The grain is very flinty and to secure the best results should be ground. According to information recently received from the station Kafir corn is highly esteemed locally as a feed for horses, many being kept throughout the year on this grain and prairie hay. Unthrashed heads are commonly fed, a head of Kafir corn being regarded as equivalent to an ear of corn. Some years ago the Mississippi Station in tests with mules found that chicken corn, a variety closely allied to Kafir corn, had about the same feeding value as maize.

## LEGUMINOUS SEEDS.

Beans and other leguminous seed resemble the cereal grains in having a low water content. In Europe horse beans are a common feeding stuff for horses. Though such feeds are known to be useful and valuable, they are seldom given to horses in the United States and few if any tests have been made with them at the American experiment stations. Müntz found that beans were quite thoroughly digested even when fed in such large quantities as 14 pounds per day. According to an English authority this amount would prove harmful, and 5 pounds of beans per day or a slightly larger quantity of peas is considered all it is desirable to feed.

## OIL CAKES AND OTHER COMMERCIAL BY-PRODUCTS.

The various cakes, gluten materials, and similar feeding stuffs are, generally speaking, commercial by-products. Thus, cotton-seed cake is the material left after the oil has been expressed from the cotton seed. In the same way, linseed cake is the residue obtained in the manufacture of linseed oil. If this cake is ground it becomes linseed meal. In the manufacture of beer the malted grain is known as brewers' grain and is best fed after drying. When starch is manufactured from corn, the nitrogenous portion of the grain is rejected and constitutes gluten feed and gluten meal. The cereal breakfast food companies have placed many feeding stuffs upon the market made up of various by-products obtained in the manufacture of their breakfast foods and similar products. These feeding stuffs vary in value, but may generally be said to represent the branny portion of the grains from which they are derived.

Several years ago the New Jersey Station reported an extended study of the value of dried brewers' grains replacing an equal weight

of oats in the ration of work horses. The uniformity in the amount of feed consumed and the weight of the animals, taken in connection with the work performed, indicates that there was no material difference in the value of the oat ration and that containing dried brewers' grains.

Timothy hay at the time being worth $18, wheat bran $17.50, corn meal $22, dried brewers' grain $17, and linseed meal $29 per ton, it was calculated a farm horse weighing 1,000 pounds can be fed for $30.84 during the six months of the year when the most work is performed if dried brewers' grain furnishes the bulk of the necessary protein, and for $33.49 if wheat bran and linseed meal are the chief sources of this nutrient. If the fertilizing value of the feeding stuffs is taken into account the difference in favor of the brewers' grains is less marked.

According to W. J. Kennedy, of the Iowa Station, gluten feed has been fed with excellent results by many prominent feeders, and is especially valuable in fitting horses for market. A ration composed of 2 parts gluten feed, 1 part bran, and 1 part soaked shelled corn was recommended. This is rich in protein and is suited to the needs of a hard-working animal. It is stated that the amount of the above mixture required averages from 12 to 14 pounds per day for a horse weighing 1,400 pounds, or in general, a pound per 100 pounds live weight.

Cotton-seed meal has been fed to a greater or less extent to horses, especially in the South, with varying results; though on the whole the weight of evidence seems to be in its favor, the North Carolina Station, for instance, finding that 2 pounds per head could be satisfactorily given as part of a mixed ration. The New Hampshire Station, as noted above, did not find cotton-seed meal as satisfactory as other materials in a mixed grain ration.

At the Louisiana Station this feed has given satisfactory results with horses and mules, 1 to 2 pounds per mule per day being fed with success. Six pounds is regarded as the maximum quantity which it is desirable to feed and animals should be led up to this amount gradually. Only bright yellow cotton-seed meal of a nutty, pleasant odor and taste should be used and no reddish or musty meal should ever be fed. As cotton-seed meal is a very concentrated feed excessive quantities should be avoided. Care should be taken that uneaten residues do not ferment in the feed boxes.

The cereal grains, ground and unground, commercial by-products, leguminous seeds, oil cakes, and similar products are very frequently called concentrated feeds, the name being suggested by the fact that, generally speaking, the food value, especially the protein content, is high in comparison with the bulk. So far as the general experience and the results of American and foreign feeding experiments go, most

of the common feeding stuffs in the group are wholesome and valuable for horses. If any one of these feeding stuffs is substituted for oats, which may be taken for a standard, the substitution should be proportional to the composition of the two feeds and not pound for pound.

## FORAGE CROPS, FRESH AND CURED.

The various forage crops—grass, clover, Kafir corn, corn, etc.—all have a high water content; that is, they are more or less succulent and juicy. They contain, however, considerable nutritive material, usually protein and carbohydrates, and are valuable feeding stuffs.

The leguminous forage crops—alfalfa, clover, cowpeas, soy beans, vetch, etc.—are richer in protein than the grasses. When the forage crops are dried and cured the resulting hay is richer in proportion to its bulk than the green material; in other words, it has been concentrated by the evaporation of the greater part of the water present. However, this is not the only change which has taken place. When hay is properly cured it undergoes a peculiar sort of fermention or oxidation which materially affects its composition.

As shown by recent investigations, fermentation improves the hay by diminishing the quantity of crude fiber and by increasing the relative amount of other nutrients, especially nitrogen-free extract. The greater the fermentation the more the crude fiber is diminished, and this is especially marked when hay is dried on racks. Hay which has undergone proper fermentation has a better flavor and agrees better with animals and is apparently more digestible than hay which has dried quickly in the sun without fermentation.

The feeding value of different forage crops, fresh and cured, depends in considerable degree upon the stage of growth, as has been shown by a number of chemical studies of the composition of different crops and cuttings of alfalfa, young and more matured corn forage, etc. Generally speaking, the nutritive value of the crop increases until growth is complete and diminishes somewhat as the plants mature or become overripe. Straw, the fully ripened stalk of cereal grains, contains some nutritive material, but is less nutritious than the same portion of the plant cut before ripening. In the perfectly ripe condition the nutritive material, elaborated in different portions of the ordinary forage plants, has been largely conveyed to the seed and used for its development or stored as reserve material.

Green forage crops are frequently preserved by ensiling. In this process the material undergoes a peculiar oxidation which correspondingly changes it in composition and food value. Some of the carbohydrates are changed into alcohol, acetic and other acids, and crude fiber is undoubtedly softened somewhat, and possibly the silage is thus rendered more digestible. Bodies having peculiar flavor and odor are also formed.

The green crops, hay, straw, other cured crops, and silage are frequently called "coarse fodder" or "roughage." This term is due to the fact that they contain a comparatively small amount of nutritive material and a high proportion of crude fiber as compared with their total bulk. Although inferior to concentrated feeds in composition, they are an essential part of the ration of horses and other farm animals, serving to give the required bulk to the food and being useful in other ways.

It is believed that unless the food, when taken into the stomach, is comparatively bulky and the mass is more or less loose in structure, it is not readily acted on by the digestive juices. The intestinal tract of the horse is long in proportion to the size of the animal, and food remains in it for several days. Experiments indicate that crude fiber, which is only slightly digestible by man, is quite thoroughly digested by horses, and even more thoroughly digested by ruminants, owing its digestibility to the fact that it is fermented for a comparatively long period by micro-organisms in the intestines.

A number of experiments have been made to learn the comparative value for horses of different forage crops, fresh and cured, the American experiment stations naturally having given their attention to the coarse fodders of most importance in this country.

The Virginia Station reported a number of trials on the value of corn silage for horses and mules. Gradually increasing amounts were fed until they were given all they could eat, with hay and grain in addition. The tests indicated that silage is a satisfactory feed provided the animals are gradually accustomed to it. The New Hampshire Station, in connection with a study of the value of different grain mixtures for work horses, compared the relative merits of timothy hay and corn stover, the two sorts of fodder being found equally valuable under the experimental conditions. From the work of the Oklahoma Station, Kafir-corn stover is said to have a feeding value about equal to corn stover. Running the stalks through a thrashing machine is considered a satisfactory method of preparing this feeding stuff.

The value of oat straw, prairie hay, and brome grass was shown by the work of the North Dakota Station, the brome grass giving as good results when fed to work horses as timothy hay. When Bermuda grass hay and timothy hay were compared at the Mississippi Station no marked differences in the cost of the rations nor in the gains made by mules were observed.

The results of extended series of experiments at the Utah Station have been very favorable to the use of alfalfa hay as a coarse fodder for horses. The fact is recognized that, like other leguminous crops, it contains a larger amount of protein in proportion to its bulk than timothy. Feeding alfalfa did not exercise any bad effects on the health

of the horses. It is stated that attacks of colic and other digestive disorders can be prevented by a judicious system of feeding. In discussing their investigations the station points out that it is absurd to claim that a horse will not eat more than is necessary if allowed the liberty of the stack and the grain bin. The argument is sometimes advanced that a horse under natural conditions, on pasture, never eats more than is necessary, and that under these conditions he is never subject to digestive disorders. While this is undoubtedly true, it must be kept in mind that as soon as the horse is stabled and required to work, he has been taken away from his natural condition and placed in an unnatural evironment.

It was observed that larger amounts of water were consumed on the alfalfa ration and that the amount of urine excreted was also larger and had a higher specific gravity. The excess, however, was never found great enough to cause any inconvenience. These experiments at the Utah Station are especially interesting since they confirm the results of twelve years' practical tests of the feeding value of alfalfa. During this period the station horses have always received this material as a coarse fodder, except when they were fed other rations for experimental purposes.

The Wyoming Station has also made some experiments which demonstrate the value of alfalfa hay as a horse feed. In discussing the subject of alfalfa for horses, the California Station says in effect that in regions where it is a staple crop the quantity of protein which can be supplied in green and cured alfalfa is so great that much less grain is required than when the coarse fodder consists of cereal hays only. For the Pacific coast, where cereal hays replace so largely those from meadow grasses, the station recommends a ration of alfalfa hay with wheat hay or barley hay and grain.

In a recent discussion of horse feeding under local conditions the Louisiana Station has pointed out the value of cowpea-vine hay.

The outcome of the different experiments is in accord with the observation of careful feeders, viz, that the various common coarse fodders may be fed to horses as circumstances demand. Although timothy hay is in many regions regarded as the preferable coarse feed, yet experience has shown that corn fodder, hay from wheat, barley, and other cereal grains, and from clover and alfalfa may be substituted for it. That this is what might be expected is shown by a study of the composition of these feeding stuffs. They resemble one another very closely in the character and amount of nutrients which they contain—alfalfa, clover, and other leguminous hays being richer in protein than the cured grasses and cereal forage. Straw is not much fed to horses in the United States, but is a common feeding stuff in Europe. As shown by its composition and digestibility it compares quite favor-

ably with other coarse fodders. In accordance with the general principle the substitution of one coarse fodder for another in a ration should always be made on the basis of composition and digestibility, rather than pound for pound.

Very few tests have been made on the comparative value of different uncured feeds or different sorts of pasturage in horse feeding, though all the common forage crops are regarded as wholesome if properly fed.

Such feed is known to be very dependent upon the fertilizer used for the crop, the method of harvesting, and the condition of the animal fed. Thus it is said that for young horses grass grown on dry land rich in lime produces compact and well-developed bone. Green fodder does not contain sufficient nutritive material in proportion to its bulk to make it an adequate feeding stuff for horses performing much work, but its importance as pasturage is well recognized.

## ROOTS AND TUBERS.

Carrots, Swedish turnips or ruta-bagas, and other roots and tubers, green vegetables, and fruits contain a high percentage of water and small amounts of the different classes of nutrients. Generally speaking, the percentage of crude fiber is smaller than in the green forage crops; but since the proportion of nutritive material is small in comparison with the total bulk, they are ordinarily referred to as coarse fodder. The use of these materials as food for horses has been attempted at different times with varying success, but it is not followed to any great extent in this country, though quite common in Europe.

Ten pounds of roots has been suggested as the maximum quantity which may be fed without unduly distending the stomach or being too laxative. "An addition of 5 or 6 pounds of carrots to the daily food ration of ordinary working horses," Captain M. H. Hayes believes, "will almost always be of benefit; and 3 pounds a day will not be too much for race horses, even in the highest state of training. It is safest to give carrots sliced longitudinally, so that they may not stick in the animal's gullet and thus choke him."

In the opinion of a recent German writer, about 12 pounds of raw potatoes per 1,000 pounds live weight may be fed to horses with advantage and, if supplemented with proper feed, there need be no fear of physiological disturbances. When fed in this amount the potatoes should be mixed with hay or cut straw to insure their being properly chewed. If small, they may be fed whole; if large, they should be sliced. In any case only ripe, healthy, unsprouted tubers should be used. It is said that horses should not be watered immediately after a ration containing potatoes.

## MOLASSES AND OTHER BY-PRODUCTS OF SUGAR MAKING.

The beet chips, diffusion residue, and other by-products obtained in the manufacture of beet sugar, consist of the sugar beet from which a considerable portion of the carbohydrates has been removed. The total amount of nutritive material present, however, is fairly large. These products, properly speaking, are coarse fodders. Molasses, which consists almost entirely of carbohydrates (sugars), was used as early as 1830 as a feed for horses, and has recently attracted considerable attention in this connection. When used for this purpose it is usually sprinkled on dry feed, being first diluted with water, or it is mixed with some material which absorbs it and renders it easy to handle, such as peat dust, or with some material rich in nitrogen, as dried blood. In the latter case the mixture more nearly represents a concentrated feed than the molasses alone, or molasses mixed with an absorbent material only. Cane-sugar molasses is also used as a feeding stuff. It differs from beet molasses, in that it contains glucose in addition to cane sugar, and has a much smaller percentage of salts.

The number of experiments which have been reported in the last few years on the feeding value of molasses is fairly large. According to the Louisiana Station, cane-sugar molasses has been extensively used for some time locally as a feed for horses and mules, many feeders keeping mules exclusively on rice bran and molasses in addition to cowpea hay. The general custom is to feed the molasses from a large trough, allowing the mules to eat it ad libitum. It is said they will consume, with apparent relish, from 8 to 12 pounds per head daily. The mules at the Louisiana Station have been fed molasses daily ad libitum for eight or ten years, and, it is stated, show its good effects "in their splendid condition, lively action, and endurance of work."

When molasses, diluted with water and sprinkled over chopped hay, was fed to some army horses in Porto Rico for about five months the condition of the horses improved. Apparently, a daily ration of 35 pounds of grass and 13 to 15 pounds of molasses per 1,000 pounds live weight was sufficient to maintain a horse in good condition. It was noted that molasses possessed some disadvantages, namely, it attracted insects, notably flies and ants, stuck to the animal's coat, smearing his face and breast, halter and halter strap, etc., and caused some trouble and delay in mixing it with the other feeds.

Other tests in the United States, France, Holland, and elsewhere have been favorable to the use of molasses as a feeding stuff, and from the results of all these, it seems fair to conclude that it can be safely fed to horses when its cost in comparison with other feeding stuffs warrants its use, a quart night and morning, diluted with water, being apparently a reasonable amount. Apart from the nutritive material molasses supplies it has a value as an appetizer and frequently renders poor hay or other feed more palatable.

In Europe favorable results have attended the use of such mixtures as blood-molasses, but these feeds are as yet little known in the United States.

## FRUITS, FRESH AND DRIED

Although horses are often given apples as they are given lumps of sugar, fruit is not generally thought of as a feeding stuff, yet its use for this purpose is by no means novel. The Arabs, it is said, commonly feed their horses fresh dates, which are apparently eaten with relish. Sometimes the dates (3 or 4 pounds at a time) are mixed with water to a sort of mush before feeding. It is believed that dates are fattening, but that they do not produce muscle.

In California, and possibly in other regions, fruit, especially prunes and other dried fruit, is sometimes fed when the market is overstocked or when for some other reason it can not be profitably sold. According to a statement recently published, small prunes of low market value have been successfully fed to horses for a long period. It is stated that the horses eat them with relish. The pits should be crushed before feeding.

All common fruits when fresh are very succulent, containing on an average 80 to 90 per cent water, the nutritive material consisting almost entirely of carbohydrates. When dried—i. e., concentrated by evaporation—they are much more nutritious. Raisins, prunes, dried peaches, etc., contain about 25 per cent water and about 70 per cent carbohydrates, of which a considerable part is sugar. The value of sugar as a nutrient is recognized, and it is not surprising, therefore, that fruits, especially after drying, should have a considerable feeding value. The feeding value of fruit has been especially studied at the California Station.

Succulent fruits or vegetables are little used in the United States, but it is interesting to note that in South Africa pumpkins are often given to horses as green feed. In Oklahoma and doubtless other regions where they are grown extensively, stock melons are fed to all farm stock, including horses, when there is a shortage of other succulent crops.

## INJURIOUS FEEDING STUFFS.

In feeding horses precautions should always be taken to avoid materials harmful in themselves, or those which have become harmful. Dirt, small stones, etc., should be removed from grain by proper screening, and all feeding stuffs should be clean.

There are a number of plants which are poisonous to horses when eaten in any considerable amount. The loco plants, mostly species of Astragalus, are ordinarily regarded as of this class. These plants have been studied by the Colorado, Kansas, South Dakota, Montana, and Oklahoma stations among others, and by this Department, but the

results obtained are not entirely conclusive. The poisonous properties of rattlebox (*Crotalaria sagittalis*) were demonstrated by the South Dakota Station, and those of some lupines by the Montana Station. According to recent experiments at the Vermont Station the common horsetail (*Equisetum arvense*) may cause poisoning when present in hay. It was found that when horses were fed cured horsetail equal in amount to not more than one-fourth of their coarse fodder ration, symptoms of poisoning were noticed, and if the feeding was continued the horses died. The symptoms of poisoning were less noticeable with young than with old horses, and also when a liberal grain ration was supplied. It was also observed that the green plant was less harmful than the dry, possibly owing to the fact that green fodder is somewhat laxative.

Feeds which are ordinarily wholesome may under certain conditions be harmful. Thus, there is a widespread and apparently justifiable prejudice against moldy or decomposing feeding stuffs. Experiments carried on at the Kansas and Indiana stations showed that the continued feeding of moldy corn induced intestinal and nervous disorders of a serious nature. It is a matter of common observation that feed which has been wet will ferment or sour readily and cause intestinal disorders. This has to be guarded against especially in warm climates.

Plants which are ordinarily wholesome may become harmful if infested with ergot. The effect of ergot on horses has been studied by the Iowa, Kansas, and Montana stations and others. It is generally conceded that the presence of ergot is a cause of rheumatism. Some feeds which are regarded as wholesome when properly fed may sometimes prove injurious if fed for a long time or in improper quantities. Thus, millet hay, in many sections of the Western United States, is believed to cause the so-called millet disease of horses. This question was studied by the North Dakota Station. It was found that long-continued feeding of millet hay caused lameness and other symptoms of poisoning, but the specific cause to which the dangerous properties of millet are due was not learned, though later work at the station indicates that it is a glucosid.

An explanation of the poisoning of stock by young sorghum and some other forage plants is offered by the discovery of a peculiar glucosid in a number of varieties of sorghum (*Sorghum vulgare*), which, under the influence of a special ferment present in the plant, liberates prussic acid. It is thought probable that this acid, which is a very active poison, may be likewise liberated in the digestive tract of animals feeding on the young plants.

For a number of years the Nebraska Experiment Station has studied sorghum poisoning, and has recently demonstrated the presence of prussic acid in the green leaves of young and old sorghum plants and Kafir corn. The poison, it is stated, is always present in at least minute traces, but becomes dangerous only when the plant is arrested by dry weather at certain stages of its growth. Sunlight, such as pre-

vails in the arid and semiarid regions of the United States, causes the development of the poison in excess.

## METHOD OF FEEDING.

The method of feeding is a subject which is often discussed, the questions of especial interest being the comparative merits of cooked and raw feed, dry and soaked grain, ground and unground grain, and cut or chaffed and uncut coarse fodder. The number of experiments which have to do with these topics is not large.

### COOKED AND RAW FEED.

One of the early French investigators compared oats and an equal volume of rye boiled until the grain burst. The results were not favorable to cooking the feed. According to another of his tests, 30.8 pounds of mashed steamed potatoes could not replace 11 pounds of hay. The potatoes were mixed with cut straw and fed cold.

It is often claimed that cooking feed increases its palatability and digestibility. The general conclusion drawn from tests with farm animals is that this belief is not warranted, and that the cost of cooking is not made up for by the increased value of the ration. It has been stated on good authority that boiled feed is useful for colts, brood mares, and stallions if fed two or three times per week, and that draft horses which are being prepared for sale or for exhibition may be given cooked feed once a day with advantage. An excellent feed for horses, it is said, may be made by boiling barley and oats in a kettle with considerable water and pouring the mass over chaffed hay, allowing the whole to stand until the hay is well softened. Bran, roots, and a small quantity of oil meal may be added also.

### DRY AND SOAKED FEED.

It is often claimed that soaking feed, especially hard grain, renders it more easily masticated and improves its digestibility. It is doubtful if the matter is as important with horses as some other classes of farm animals. It has been found in experimental tests that healthy horses with good teeth digested dry beans and corn as well as the same materials which had been soaked in water for 24 hours.

Soaking or wetting feed may sometimes be of importance as regards the health of horses. According to the experience of an English feeder, chaffed straw, which was fed on account of a shortage in the hay crop, gave better results when soaked than when dry. The dry material caused colic and constipation. It was also observed that the horses relished soaked grain (corn and oats 1:1).

It is believed that the dust in hay causes heaves, and to avoid such trouble both long and cut hay, especially clover, is very often dampened before feeding, to lay the dust.

## GROUND AND UNGROUND FEED.

Opinions differ as regards the advantages of grinding grain. For horses which are out of the stable during the day and worked hard, it is quite generally believed that all grains, with the possible exception of oats, should be ground, and for those at extremely hard work, all grain should be ground and mixed with chaffed hay. For idle horses oats or grain should not be ground, nor should hay or straw be chaffed. In other words, provided the animals have time to masticate their ration thoroughly, grinding is not necessary. When this is not the case, grinding takes the place of thorough mastication to some extent, and increases the assimilation of the ration.

When whole oats were compared with ground wheat and bran at the North Dakota Station, the horses fed the former ration ate somewhat more and showed a slight loss in weight, while doing a little less work than those fed the ground grain. At the Utah Station, tests of the comparative merits of ground and unground corn, oats, and wheat fed under different experimental conditions indicated that the ground and unground grains were equally satisfactory. When whole and ground oats, corn, and barley were compared for colts at the Iowa Station, somewhat larger gains were made on the ground feed.

The comparative digestibility of different ground and unground feeding stuffs was tested at the Maryland Station. It appeared that ground corn and oats were more thoroughly digested than the unground grain. In this connection it may be noted that similar results have been obtained in tests with other farm animals, but it is commonly believed that the difference in digestibility is often not sufficient to pay for the cost of grinding.

From all the American tests, and those which have been made in Europe, it appears fair to say that there is no very marked advantage in grinding grain for healthy horses with good teeth.

## CUT AND UNCUT COARSE FODDER.

It is perhaps the general opinion that when horses have ample time for chewing and digesting their feed there is no necessity for chaffing or cutting hay and straw. When the time for feeding is limited chaffing and cutting coarse fodder is regarded as advantageous. This is an item of special importance with hard-worked horses kept in the stable only at night. Furthermore, chaffed feed occupies less space for storage than uncut hay or straw, and can be readily handled. Shredding corn fodder is regarded as an economical practice, but apparently few experiments on the comparative merits of shredded and whole corn fodder for horses have yet been reported. No marked variation was observed in the weights of two lots of horses fed whole

and cut timothy or whole and cut alfalfa and clover hay mixed in a test carried on at the Utah Station.

At the Maryland Station, in studies of the digestibility of a number of whole and ground feeds, it was found that grinding corn shives—i. e., cornstalks from which the blades, husks, and pith are removed—until the material resembled coarse bran did not destroy its value as a coarse fodder, and that the finely ground material supplied the necessary bulk to the ration as well as the same material unground. It was further claimed that the finely ground coarse fodder possessed an advantage over the unground material in that it could be mixed with grain to form a well-balanced ration and fed to horses on shipboard, or under similar conditions, more readily than unground fodder and grain.

## FATTENING HORSES FOR MARKET.

Fattening horses so that they will reach market in good condition for sale is quite an important industry in some regions. For instance, in Iowa there are a number of feeders who thus prepare large numbers of horses for the Chicago market, and officials of the Iowa Experiment Station have gathered some data on the subject. The general practice is to feed generously and give little exercise. With proper feeding and care, as many as a dozen horses of a lot fed for market have in some instances made an average gain of 3.75 pounds per head per day throughout a period of ninety days. Somewhat larger gains have been made under exceptional circumstances.

## WATERING HORSES.

A discussion of the subject of watering horses should take into account the reasons why water is needed, the amounts required, the proper time for watering, and related topics.

Horses, like other animals, require water, which should always be of good quality, for moistening their food, so that the digestive juices may permeate it readily, for diluting the blood and other fluids of the body, and for other physiological uses. It may be assumed that under any given normal condition the body contains a definite amount of water. When any considerable amount of water is lost from the body, a sensation of thirst is experienced, showing that more water is needed to take its place. Practically all the water excreted leaves the body in the feces, urine, perspiration, and breath. The amount eliminated in each increases with the amount of water consumed, the largest amount being excreted in the feces.

In addition to the water drunk by horses, a considerable amount is obtained in the more or less succulent food eaten. The amount of water required is influenced by a number of factors, including the

season of the year, temperature of the surrounding air, character of the feed, the individual peculiarities of the horse, the amount and character of the work performed, and probably others. The amount of water needed increases with the temperature and with the amount of work performed, since it is very evident that both of these factors increase the amount which is given off from the body in the form of perspiration. Muscular work also increases the amount of water vapor excreted in the breath.

It has been found that less water is required when the ration consists largely of concentrated feed than when large amounts of coarse fodder are consumed, and it is a matter of common observation that less water is consumed when green, succulent feeds form a considerable part of the ration than when it consists of dry feed. That the amount of water taken, even in dry feed, may be considerable is shown by the fact that a ration of 12 pounds of oats and 15 pounds of hay furnishes some 4 pounds of water. A succulent ration would furnish much more.

In general, a horse will drink from 50 pounds or less to 65 pounds per day, though under the influence of warm weather or hard work the amount may range from 85 to 110 pounds or over. In some experiments in the British army it was found that when allowed to choose, horses drank about one-fourth of their daily allowance in the morning and not far from three-eighths at noon and about the same proportion at night.

In connection with a number of the tests at the experiment stations in the United States the amount of water consumed has been recorded. At the New Hampshire Station, on a ration of different grain mixtures, with timothy hay and corn fodder, the quantity of water varied from 71 to 90 pounds of water per head per day, both the ration consumed and the amount of work performed influencing the quantity of water drunk, although the individuality of the horse had the most marked effect. At the Utah Station it was found that larger amounts were consumed on alfalfa hay with oats than on timothy hay, the greater consumption of water on the former ration inducing a greater elimination by the kidneys; but so far as could be observed this was not attended by any bad results, nor was it found inconvenient.

A pair of mules, at the Oklahoma Station, during the hot summer weather, drank 113 pounds of water per head daily, and on one day 175 pounds. In another test, at moderate work, the amount recorded was 107 pounds. In these tests the grain ration consisted of Kafir corn, maize, oats, and bran.

The proper time to water horses is a matter concerning which opinions differ. Many feeders believe that they should be watered before feeding, while others are equally certain that feeding should precede watering. Some extended experiments have been recently

made in Europe which have led to definite conclusions, and seem to have reached the truth in the matter.

The rations fed consisted of different mixtures of corn, oats, hay, and straw, and a number of experiments were made in which the only condition which varied was the time of watering. In some of the tests the horses drank before and in some after eating, and in others after the grain portion of the ration was eaten, but before the hay.

So far as was observed the time of drinking had no effect on the digestibility of a ration of grain and hay. When hay only was fed there seemed to be a slight advantage in watering before feeding. The general conclusion was drawn that horses may be watered before, during, or after meals without interfering with the digestion and absorption of food. All these methods of watering are equally good for the horse, and each of them may be employed according to circumstances. It is obvious that certain circumstances may make it necessary to adopt one or the other method. For instance, after severe loss of water, such as occurs in consequence of long-continued, severe exertion, the animal should always be allowed to drink before he is fed, as otherwise he will not feed well.

In this connection it is worth noting that many American farmers believe that watering before feeding is best. Although all methods of watering seemed in these tests to be equally good for the horse, it is not desirable to change unnecessarily from one method to another. Animals, or at least some of them, appear to be not altogether indifferent to such a change. In the experiments referred to above it was found that whenever a change was made from the plan of watering after feeding to that of watering before, the appetite fell off for some days; not that the horses did not consume the whole of the food given to them, but for some days together they did not eat with the same avidity as before, and took a longer time to consume their rations completely. A similar effect was not observed when the change was from watering before to watering after feeding, or from watering after to watering during meals, or when the change was in the opposite direction to the last. It seems best, therefore, to avoid sudden and unnecessary changes in the method of watering.

## DIGESTIBILITY OF FEEDING STUFFS.

In the preceding pages reference has been made to the composition of different feeding stuffs and to tests of the comparative value of different concentrated feeds and coarse fodders. The real value of any feeding stuff is determined, not alone by its composition, but also by its digestibility; that is, by the amount of material which it gives up to the body in its passage through the digestive tract. It is evident that if two feeding stuffs have practically the same composition, but one gives up more material to the body than the other—that is, is

more thoroughly digested—it must actually be more valuable than the other material. The bulk of the substance of almost all feeding stuffs is insoluble when eaten. Only material in solution can pass through the walls of the stomach and intestines into the circulation and be utilized by the body, therefore digestibility consists chiefly in rendering insoluble materials soluble. This is effected by the aid of digestive ferments and also by bacteria.

Digestion experiments are frequently made to learn how thoroughly a given feeding stuff or ration is assimilated. The usual method is to feed the material under consideration for a longer or shorter time, the amount and composition being determined. From the total nutrients consumed, the amounts excreted undigested in the feces are deducted, showing the amount of each retained in the body. It is the usual custom to express the amounts digested in percentages, the results thus obtained being termed coefficients of digestibility.

The digestibility of a number of different feeding stuffs has been tested with horses in this country and in Europe, although the number of such experiments is much smaller than in the case of cattle and sheep. The most extended series of American experiments with horses was carried on at the Maryland Experiment Station.

The average results of the available digestion experiments with horses were used to compute the digestible nutrients furnished per 100 pounds by the different feeding stuffs included in the table on page 10.

It has been found that in the majority of the feeding stuffs tested the percentage of protein digested is fairly high, being greater in grains and seeds than in hay and grasses, and least in the case of timothy hay and spelt straw.

Generally speaking, the values obtained for the digestibility of fat are rather low, the fat of oats being most digestible and that of peas least digestible. There are reasons connected with the analytical methods commonly followed which render the results obtained with fat not altogether satisfactory.

Nitrogen-free extract is quite thoroughly digested by horses, the values ranging, in a number of experiments, from 100 per cent in the case of molasses to 17.9 per cent in the case of spelt straw. The principal sources of nitrogen-free extract in the ration are the cereal grains and their by-products, and it is interesting to note that the coefficients of digestibility of nitrogen-free extract of these materials is high. In the majority of feeding stuffs the crude fiber is not very thoroughly digested, the coefficients of digestibility being on an average less than 50 per cent.

## COMPARATIVE DIGESTIBILITY BY HORSES AND RUMINANTS.

In computing the digestible nutrients furnished by different feeding stuffs, it has been a common custom to use available data obtained from digestion experiments with farm animals without distinguishing

between ruminants, like the cow, sheep, etc., and nonruminants, like the horse, although differences had been pointed out by a number of observers. Averaging the results of a considerable number of tests, it appears that ruminants digest 26.9 per cent more protein, 5.4 per cent more fat, 16.7 per cent more nitrogen-free extract, and 4 per cent more crude fiber from timothy hay than horses. In the case of oats, the amounts of protein digested were practically the same, but the ruminants surpassed the horses by 12.8 per cent for the fat and 0.5 per cent each for the nitrogen-free extract and crude fiber. Similar results were obtained with other coarse fodders and concentrated feeds. Considering all the available experiments bearing on this subject, it seems fair to conclude that in general ruminants digest a larger percentage of fat, carbohydrates, and crude fiber than horses, the differences being most marked in the case of the crude fiber. These results are in accord with what might be expected from differences in the digestive organs of the different classes of animals. It is well known that fineness of division is an important factor in considering the thoroughness of digestion. The length of time any given food material remains in the digestive tract is also important. The ruminants have an opportunity to chew their food more thoroughly than horses and retain it longer in the digestive tract. It is said that on an average horses retain their food 4 days or less; cattle 3 or 4 to 7 or 8 days; sheep or goats from 3 or 4 days with ordinary rations to 7 or 8 days when straw is eaten. That the food is actually more finely divided by ruminants in chewing and digesting is indicated by the mechanical condition of the manure, that from horses containing an abundance of fairly large fragments of hay and other coarse fodders, etc., while the manure of cattle commonly contains undigested residue in a finer state of division. In the case of sheep the manure contains the undigested residue in still smaller fragments. It is perhaps generally believed that crude fiber is chiefly digested by the action of bacteria in the intestine, and it is obvious that the longer materials remain in the intestine the greater the opportunity for the action of such micro-organisms.

The fact that, other things being equal, horses digest their feed less thoroughly than cattle, i. e., retain less nutritive material from any given ration when it passes through the digestive tract, has been long recognized. For this reason horse manure is richer than manure from cattle on the same ration. In other words, the horse manure contains a larger proportion of the ration than cow manure, and hence, more of the nitrogen and mineral matter, especially phosphoric acid and potash, originally present in the feed.

The value of the manure produced by horses was studied by the Pennsylvania Station. Observations made with a number of horses indicate that a horse produces annually about 12,700 pounds of fresh

manure, not including the amount dropped while at work. This quantity, which would be worth about $13.50 as fertilizer, would require the use of about 2,500 pounds of straw for bedding. According to the author's calculations a ton of wheat straw economically used for bedding horses may result in 6 tons of fresh manure, although in general practice the amount is not likely to exceed 5 tons and may be much less if few animals are kept or the manure is infrequently removed.

## RATIONS ACTUALLY FED AND FEEDING STANDARDS.

The amount of the different feeding stuffs required and hence the quantity of nutrients supplied to horses may be learned by observation or experiment or a combination of the two methods. Doubtless all practical horse feeders supply rations which they believe are suited to their horses' needs, and in stables where horses are fed in any considerable number economy demands that the amount fed shall be fixed and not vary according to the whims of the feeder. When the feeding stuffs used are weighed and the condition of the horses is noted, a feeding experiment results. Using average values obtained from many more or less complicated feeding experiments and other investigations, so-called feeding standards have been devised which are designed to show the amount of protein, fat, and carbohydrates required per day for various conditions of work and rest. For the sake of uniformity, the standards are usually calculated on the basis of 1,000 pounds live weight. They often show in addition the nutritive ratio; that is, the ratio of protein to the sum of the carbohydrates and 2.25 times the fat. It is also possible to express the feeding standards in terms of protein and energy, since the functions of food, as previously stated, are to build and repair tissue and supply energy, protein alone serving for the former purpose, while all the nutrients yield energy. The best known feeding standards for horses and other farm animals are those computed by Wolff and revised by Lehmann.

Very frequently so-called standards for horses have been proposed which have shown the quantities of feeding stuffs required; for instance, the pounds of oats and hay needed per day per 1,000 pounds live weight. Such standards, or more properly standard rations, have been adopted in many countries for army horses, and in other cases where large numbers of horses are fed under uniform conditions. The digestible nutrients furnished by such standard rations can be calculated by the aid of figures showing the average composition and digestibility of the feeding stuffs.

The table following shows the amount of nutrients and energy furnished per 1,000 pounds live weight by rations supplied the U. S. Army horses, by those fed to a number of farm horses at the stations,

and work horses employed by packing houses, express companies, and other companies, and also the average nutritive value of a considerable number of such rations fed in different parts of the United States, as well as the commonly accepted feeding standards. The amount of digestible nutrients furnished by the rations is also included, such data having been calculated by the aid of figures recorded elsewhere (see page 10).

TABLE 2.—*Rations actually fed to horses and digestible nutrients and energy in rations calculated to basis of 1,000 pounds live weight.*

| Kind of horses. | Weight of horses. | Rations actually fed. | Nutrients in ration per 1,000 pounds live weight. | | | | Digestible nutrients in ration per 1,000 pounds live weight. | | | | Energy in digestible nutrients. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Protein. | Fat. | Nitrogen-free extract. | Crude fiber. | Protein. | Fat. | Nitrogen-free extract. | Crude fiber. | |
| ARMY HORSES. | | | | | | | | | | | |
| United States: | *Lbs.* | *Pounds.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Calories.* |
| Cavalry | 1,050 | Oats, 12; Hay, 14 | 2.14 | 0.90 | 12.82 | 4.95 | 1.25 | 0.57 | 8.00 | 1.97 | 23,300 |
| Artillery | 1,125 | Oats, 12; Hay, 14 | 2.00 | .84 | 11.96 | 4.62 | 1.16 | .53 | 7.48 | 1.84 | 21,750 |
| Mules | 1,025 | Oats, 9; Hay, 14 | 1.84 | .78 | 11.39 | 4.80 | 1.00 | .48 | 6.88 | 1.94 | 20,250 |
| HORSES WITH LIGHT WORK. | | | | | | | | | | | |
| Driving horse, Wyoming Station. | 1,200 | Alfalfa, 21.25; Straw, 3.2 | 2.38 | .18 | 5.87 | 2.34 | 1.76 | .05 | 3.58 | .92 | 11,855 |
| Carriage horse | 1,050 | Oats, 10; Hay, 12 | 2.06 | .76 | 10.42 | 3.87 | 1.40 | .40 | 6.97 | 1.44 | 19,935 |
| Average | | | 2.22 | .47 | 8.15 | 3.10 | 1.58 | .22 | 5.27 | 1.18 | 15,895 |
| Fire company horses: | | | | | | | | | | | |
| Boston, Mass | 1,400 | Ground grain, 9.38; Hay, 18 | 1.65 | .68 | 9.57 | 4.57 | .87 | .41 | 6.14 | 1.73 | 18,000 |
| Chicago, Ill | 1,350 | Oats, 4; Hay, 15 | 1.00 | .43 | 6.77 | 3.50 | .42 | .24 | 3.70 | 1.45 | 11,365 |
| Average of 6, including above. | | | 1.35 | .56 | 7.95 | 3.20 | .78 | .35 | 4.99 | 1.26 | 14,555 |
| General average for light work. | | | 1.57 | .54 | 8.00 | 3.18 | .99 | .32 | 5.06 | 1.24 | 14,890 |
| HORSES WITH MODERATE WORK. | | | | | | | | | | | |
| Express horses: | | | | | | | | | | | |
| Richmond, Va., summer. | 1,400 | Corn, 4.67; Oats, 5.33; Bran, 0.83; Corn meal, 4.16; Hay, 15 | 1.79 | .78 | 11.78 | 3.64 | .97 | .45 | 8.19 | 1.46 | 21,650 |
| Jersey City, N.J | 1,325 | Corn, 2; Oats, 19; Bran, 1.5; Hay, 9.5 | 2.45 | 1.03 | 13.45 | 3.57 | 1.66 | .67 | 9.37 | 1.32 | 25,800 |
| Boston, Mass | 1,325 | Corn, 12; Oats, 5.25; Hay, 20 | 2.38 | 1.04 | 14.96 | 5.32 | 1.28 | .60 | 9.75 | 2.12 | 27,000 |
| Average of 4, including above. | | | 2.15 | .93 | 13.27 | 4.13 | 1.26 | .55 | 9.06 | 1.62 | 24,550 |

TABLE 2.—*Rations actually fed to horses and digestible nutrients and energy in rations calculated to basis of 1,000 pounds live weight*—Continued.

| Kind of horses. | Weight of horses. | Rations actually fed. | Nutrients in ration per 1,000 pounds live weight. Protein. | Fat. | Nitrogen-free extract. | Crude fiber. | Digestible nutrients in ration per 1,000 pounds live weight. Protein. | Fat. | Nitrogen-free extract. | Crude fiber. | Energy in digestible nutrients. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| HORSES WITH MODERATE WORK—continued. | | | | | | | | | | | |
| Cab horses: | *Lbs.* | *Pounds.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Calories.* |
| Washington, D. C. | 1,200 | Oats, 10; Corn, 5; Hay, 23 | 2.56 | 1.12 | 16.50 | 6.43 | 1.28 | 0.63 | 10.42 | 2.60 | 29,250 |
| San Francisco, Cal. | 1,350 | Oats, 8; Hay, 16 | 1.39 | .59 | 8.87 | 4.00 | .70 | .36 | 5.21 | 1.64 | 15,550 |
| Average of 4, including above. | ...... | ................ | 1.88 | .80 | 11.51 | 4.30 | 1.06 | .49 | 7.33 | 1.72 | 20,860 |
| Farm horses: | | | | | | | | | | | |
| Wyoming Station | 1,000 | Alfalfa, 13.75; Straw, 2.25 | 1.85 | .14 | 6.27 | ...... | 1.37 | .03 | 4.03 | ...... | 8,240 |
| New Hampshire Station. | 1,235 | Bran, 2; Corn, 6; Gluten meal, 6; Hay, 10 | 2.37 | .93 | 10.49 | 2.90 | 1.59 | .64 | 7.47 | 1.03 | 21,465 |
| New Jersey Station | 1,000 | Hay, 6; Bran 2 1/7; Corn, 4 3/7; Dried brewers' grain, 8 4/7. | 3.21 | .89 | 10.81 | 3.09 | 2.22 | .65 | 6.99 | 1.38 | 22,440 |
| Massachusetts Station. | 1,100 | Hay, 18; Wheat bran, 2. Provender, 6= crushed corn, 2.73; oats, 3.27. | 1.85 | .76 | 11.85 | 5.25 | .85 | .41 | 7.04 | 2.14 | 20,385 |
| Utah Station | 1,370 | Alfalfa hay, 25. Bran and shorts (1:1), 10. | 3.72 | .71 | 11.83 | 5.16 | 2.81 | .29 | 8.27 | 1.96 | 25,480 |
| Do | 1,325 | Timothy hay, 22.8. Bran and shorts (1:1), 10. | 2.17 | .75 | 11.93 | 5.61 | 1.11 | .42 | 6.56 | 2.31 | 20,345 |
| Average of 41, including above. | ...... | ................ | 2.46 | .75 | 11.92 | 4.05 | 1.57 | .40 | 8.09 | 1.62 | 22,760 |
| General average for moderate work. | ...... | ................ | 2.38 | .77 | 11.99 | 4.08 | 1.49 | .42 | 8.09 | 1.63 | 22,710 |
| Farm mules, Virginia Station. | 1,310 | Hay, 15.2; Corn, 10.5; Corn silage, 10.5. | 1.70 | .82 | 12.00 | 4.00 | .72 | .42 | 8.22 | 1.75 | 21,655 |
| Average of 6, including above. | ...... | ................ | 1.64 | .78 | 11.54 | 3.74 | .69 | .39 | 7.95 | 1.60 | 20,675 |
| HORSES WITH SEVERE WORK. | | | | | | | | | | | |
| Truck and draft horses: | | | | | | | | | | | |
| Chicago, Ill., daily ration. | 1,500 | Oats, 7.5; Hay, 20 | 1.38 | .58 | 8.99 | 4.34 | .64 | .34 | 5.11 | 1.79 | 15,450 |
| South Omaha, Nebr. | 1,500 | Oats, 15; Hay, 12 | 1.65 | .70 | 9.57 | 3.27 | 1.04 | .45 | 6.23 | 1.27 | 17,800 |
| Average of 5, including above. | ...... | ................ | 1.80 | .76 | 10.49 | 3.49 | 1.12 | .49 | 6.94 | 1.35 | 19,560 |

TABLE 2.—*Rations actually fed to horses and digestible nutrients and energy in rations calculated to basis of 1,000 pounds live weight*—Continued.

| Kind of horses. | Weight of horses. | Rations actually fed. | Nutrients in ration per 1,000 pounds live weight. | | | | Digestible nutrients in ration per 1,000 pounds live weight. | | | | Energy in digestible nutrients. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Protein. | Fat. | Nitrogen-free extract. | Crude fiber. | Protein. | Fat. | Nitrogen-free extract. | Crude fiber. | |
| FEEDING STANDARDS AND AVERAGE RATIONS. | *Lbs.* | *Pounds.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Calories.* |
| Light work, Wolff-Lehmann. | ...... | ...... | ...... | ...... | ...... | ...... | 1.5 | .40 | 9.5 | | 22,150 |
| Medium work, Wolff-Lehmann. | ...... | ...... | ...... | ...... | ...... | ...... | 2.0 | .60 | 11.0 | | 26,700 |
| Heavy work, Wolff-Lehmann. | ...... | ...... | ...... | ...... | ...... | ...... | 2.5 | .80 | 13.3 | | 32,750 |
| Maintenance, moderate work, original, Grandeau. | ...... | ...... | ...... | ...... | ...... | ...... | 2.14 | .52 | 11.15 | | 26,900 |
| Maintenance, moderate work, modified, Grandeau. | ...... | ...... | ...... | ...... | ...... | ...... | 1.95 | .44 | 9.93 | | 23,950 |
| Paris Bus Co., horses, Lawes & Gilbert's computation. | ...... | ...... | ...... | ...... | ...... | ...... | 1.60 | .40 | 12.14 | | 27,200 |
| Ordinary work, Lavalard. | ...... | ...... | ...... | ...... | ...... | ...... | 1.10 | ...... | [a]11.0 | | 22,510 |
| Severe work, Lavalard | ...... | ...... | ...... | ...... | ...... | ...... | 1.30 | ...... | [a]11.0 | | 22,880 |
| AMERICAN EXPERIMENTS. | | | | | | | | | | | |
| Horses with light work: | | | | | | | | | | | |
| Driving horses .... | ...... | ...... | ...... | ...... | ...... | ...... | 1.58 | .22 | 5.27 | 1.18 | 15,895 |
| General average... | ...... | ...... | ...... | ...... | ...... | ...... | .99 | .32 | 5.06 | 1.24 | 14,890 |
| Horses with moderate work: | | | | | | | | | | | |
| Express and cab horses. | ...... | ...... | ...... | ...... | ...... | ...... | 1.06 | .49 | 7.33 | 1.72 | 20,860 |
| Farm horses....... | ...... | ...... | ...... | ...... | ...... | ...... | 1.57 | .40 | 8.09 | 1.62 | 22,760 |
| General average... | ...... | ...... | ...... | ...... | ...... | ...... | 1.49 | .42 | 8.09 | 1.63 | 22,710 |
| Mules with moderate work: Farm mules. | ...... | ...... | ...... | ...... | ...... | ...... | .69 | .39 | 7.95 | 1.60 | 20,675 |
| Horses with severe work: Truck and draft horses. | ...... | ...... | ...... | ...... | ...... | ...... | 1.12 | .49 | 6.94 | 1.35 | 19,560 |

[a] This value represents total carbohydrates plus 2.25 times the fat.

As will be seen, the average values for the protein and energy in the rations of the horses performing light work are considerably less than similar values for horses performing moderate work. The data for the former group is much more limited than for the latter, but the relation is in accord with the commonly accepted theories. The farm mules consumed a ration furnishing less protein and practically the same amount of energy as horses performing similar work, though the tests with mules are too few for general deductions. The rations of the truck and draft horses performing severe muscular work furnished less protein and energy on an average than the rations of the horses

with moderate work. This is not in accord with commonly accepted theories, for it is generally conceded that horses at severe work require larger rations than those at moderate work. The discrepancy may be explained in part perhaps by the fact that the data for the group performing severe work is much less extended than that for the group performing moderate work. There is every reason to suppose that the truck and draft horses received rations sufficient for their needs, as the firms owning them are known to make the effort to maintain their horses in good condition. Such truck and draft animals are often employed at work which is performed at a slow pace, and undoubtedly this has a bearing on the fact that they were able to perform a large amount of work on a comparatively small ration, as the speed at which work is performed has a marked effect upon the food requirements.

The average values, representing the amounts which were fed to American horses performing light, moderate, and severe work, differ somewhat from the commonly accepted feeding standards. It would be going too far to propose the adoption of these average values as standards in the place of those which have been commonly accepted. It is undoubtedly true that a feeding standard should be based on other data than the results of feeding experiments; however, in so far as the results represent the average practice of successful feeders they are worthy of consideration, and certainly emphasize the importance of undertaking investigations with a view to revising the standards. It should be remembered that the amounts of digestible nutrients in the rations actually fed were calculated with the aid of coefficients of digestibility obtained with horses and are, therefore, considerably lower than would be the case if average values obtained with ruminants had been used, a method of calculation which has been often followed in the past, but which does not seem desirable.

The number of feeding stuffs used in making up the rations fed was not found to be large, oats and corn being the common grains, and hay, usually timothy, the common coarse fodder. The amounts of nutrients and energy in the different rations of the horses making up the different groups varied within rather wide limits, which is not surprising when it is remembered that the horses were fed under many different conditions and by a large number of feeders whose opinions regarding what constituted a proper ration naturally differed.

The rations given in Table 2 and those used in calculating the averages there included were believed to be sufficient for the horses' needs either because the animals maintained a practically constant weight, as in the case of the horses fed at the experiment stations, or because the rations had stood the practical test of usage at the hands of express companies, cab companies, etc. Several additional rations follow, which may perhaps serve as a guide in determining the kind and

amount of feeds which should be given to work horses under different conditions.

The New Hampshire Station found that the following rations were moderate in cost and sufficient in amount for farm horses weighing between 1,200 and 1,300 pounds:

Ration No. 1. Timothy hay 10 pounds, bran 2 pounds, corn 6 pounds, and gluten feed 6 pounds.

Ration No. 2. Timothy hay 10 pounds, corn 8 pounds, and bran 7 pounds.

Ration No. 3. Timothy hay 10 pounds, corn 8 pounds, and linseed meal 4 pounds.

As shown by correspondence a favorite ration with feeders in different cities for truck horses weighing some 1,500 pounds is made up of 15 to 20 pounds of oats and 12 to 20 pounds of hay. Some feeders prefer corn and oats in equal parts instead of oats.

In Table 2 the ration for army horses weighing about 1,100 pounds is given as oats 12 pounds and hay 14 pounds. According to the army regulations a like amount of corn or barley may be supplied in the place of oats.

The Iowa Station work horses, weighing 1,200 pounds, according to a recent publication, are fed 12 pounds of hay and 12 pounds of grain (oats, corn, and bran 3:2:1) per head daily. If oats are high in price the amount of corn is increased, the grains being mixed in the proportion of 2:2:1. Horses weighing 1,500 to 1,600 pounds receive 15 pounds of hay and 15 pounds of the above grain mixture. This, it is said, has been found sufficient to keep them in good flesh during heavy work. For ordinary work horses weighing about 1,300 pounds a ration of 10 pounds of oat straw and 15 pounds of equal parts of corn and oats by weight is considered sufficient. At severe work the mixture should consist of 3 parts of oats to 2 of corn.

The California Station recommends, per 1,000 pounds live weight, the following combinations among others as suited to Pacific coast conditions:

Ration No. 1. Alfalfa hay 12 pounds, wheat hay 11 pounds, and crushed barley 7 pounds.

Ration No. 2. Alfalfa hay 10 pounds, barley hay 12 pounds, and cracked corn 7 pounds.

As a sample of a ration containing molasses the following may be cited which has been satisfactorily fed to a large number of draft horses averaging 1,700 pounds in weight: Night and morning a quart of molasses diluted with 3 quarts of water and thoroughly mixed with 6 pounds of cut hay of good quality, 1.5 quarts of corn meal, and 2.5 quarts of coarse bran. In addition the horses were given 5 quarts of dry oats in the middle of the day and 11 pounds of long hay at night.

An English authority recommends the ration given below, which is interesting as an example of the use of roots: For work horses 12 pounds of oats, 15 pounds of hay, and 5 pounds of carrots. A more

abundant ration suited to more severe work is 20 pounds of oats, 10 pounds of hay, and 3 pounds of carrots.

For farm horses at light work Settegast recommends 6 to 10 pounds oats, 6 to 9 pounds hay, and 3 pounds straw. For medium work 10 pounds oats, 10 pounds hay, and 3 pounds straw. For heavy work 13 pounds oats, 12 pounds hay, and 3 pounds straw.

A ration proposed by Sidney for a draft horse at heavy work is of interest because beans replaced some of the grain ordinarily fed. The ration consists of 13 pounds oats, 6 pounds beans, 3 pounds corn, and 15 pounds chaffed clover hay.

The above rations are not especially recommended, but are quoted as illustrations of the ways in which feeding stuffs can be combined. Each feeder should decide upon a ration which makes the most economical use of the local feed supply, taking care that it furnishes in reasonable combination nutritive material sufficient for the amount of work required.

## METHOD OF CALCULATING RATIONS.

The feeding value of any ration may be readily calculated and compared with the standards. Suppose a horse at moderate work and weighing 1,200 pounds is fed 11 pounds of oats and 10 pounds of timothy hay daily. The Wolff-Lehmann feeding standard for horses at moderate work calls for 1.8 pounds of protein and 26,700 calories per thousand pounds live weight. A horse weighing 1,200 pounds would therefore require 1.2 times as much, or 2.2 pounds protein and 32,000 calories. Oats contain 9.39 pounds of digestible protein and 122,100 calories per hundred pounds. Eleven pounds would therefore furnish 1.03 pounds of protein ($9.39\times0.11=1.03$), and 13,431 calories ($122,100\times0.11=13,431$). Timothy hay furnishes 1.25 pounds protein and 69,850 calories per hundred pounds. Ten pounds would therefore furnish 0.13 pound protein ($1.25\times0.10=0.13$) and 6,985 calories ($69,850\times0.10=6,985$). The sum of the nutrients furnished by 11 pounds of oats and 10 pounds of hay would therefore be 1.16 pounds protein and 20,415 calories, or 1.04 pounds protein and 11,585 calories less than the standard calls for. This may be made up by adding more oats, hay, or other feeding stuff. The amount of oats required to furnish the necessary protein may be learned from the proportion $100:9.39::x:1.04$; or, in other words, by dividing 104 by 9.39, which gives 11.07. This quantity of oats would also furnish 13,517 calories, making the total protein of the ration 2.2 pounds and the total fuel value 33,932 calories. The fuel value of the ration is in excess of the standard, though the agreement is close enough for all practical purposes.

It will be remembered that it is not necessary that the amounts furnished in a ration shall exactly equal those called for by the standard, but rather that they approximate them, being greater rather

than less through a long period. Rations which will furnish the amounts called for by other feeding standards, or by the average values deduced from American rations, can, of course, be calculated in the same way. As will be noted, the amount of feeding stuffs necessary to provide nutrients equal to the amount called for by the Wolff standard for a horse at moderate work is large compared with the amounts ordinarily used in this country.

## MUSCULAR WORK AND ITS EFFECT ON FOOD REQUIREMENTS.

It is commonly said that the amount of food required by horses is proportionate to their weight; it being self-evident that a large horse would require more material than a small horse to build and repair the body and to carry on all the vital processes which constitute internal muscular work. Investigations have shown that the requirements are more nearly proportional to the surface areas than to the body weight. Individual peculiarity is, of course, a factor which must be reckoned with, but the general statement is justified. The factor which has the greatest influence on the ration required is the amount of work performed, the ration increasing with the work. When horses which have been consuming a large ration and performing work are compelled to rest, even for a few days, the ration should be diminished.

In order to study the effects of work upon the amount of food required it is necessary to have some means of measuring and comparing the different kinds of work done.

### MEASURING MUSCULAR WORK.

It has been said already that the total work performed by a horse consists of internal and external muscular exertion. The former includes the force expended in the digesting of food, the beating of the heart, etc.; the latter that expended in moving the body, i. e., in the motion of forward progression, and in drawing or carrying a load. The latter factor is the one of most importance in considering the horse as a beast of burden. The amount of such muscular work has been calculated or measured in various ways. The methods of calculation are often complex and need not be discussed in detail.

According to the classic experiments of James Watts, a horse can exert a power equal to 33,000 foot-pounds per minute, i. e., in one minute can exert a force sufficient to raise 33,000 pounds 1 foot. This value has been termed one horsepower and has been accepted as a common unit for the measurement of force. In countries where the metric system is employed the more common unit is the kilogrammeter. This unit is equal to 7.2 foot-pounds. According to Watts's values, a horse working eight hours per day would perform work represented by $33{,}000 \times 60 \times 8 = 15{,}840{,}000$ foot-pounds. Later estimates give

lower values. It has been calculated that an average horse will produce only about 22,000 foot-pounds per minute, which would be equivalent to 10,560,000 foot-pounds in a working day of eight hours.

According to German experiments, the day's work of a horse hauling a load eight hours on a level road amounted to 7,999,800 foot-pounds. Working the same length of time with a dynamometer the work amounted to 12,996,000 foot-pounds. Larger values have been obtained in calculations representing the amount of work performed daily by army horses.

Taking into account the average amount of muscular work expressed in foot-pounds, the speed at which work is performed, the duration of the work, and the amount of work done at a walk and trotting, the total work done per day by French army horses carrying a rider weighing 175 pounds without a pack, and 265 pounds with a pack, and 200 pounds with accouterment for maneuvers, has been calculated to be as follows:

TABLE 3.—*Work performed by French army horses per day.*

| Work per day. | Weight carried. | Velocity per second. | Work per second. | Duration of daily work. | Amount of work at different gaits. |
|---|---|---|---|---|---|
| ORDINARY WORK (RIDER WITHOUT PACK). | *Pounds.* | *Feet.* | *Foot-lbs.* | *Hrs. min.* | *Foot-lbs.* |
| Walking | 176 | 5.446 | 958.5 | 2 30 | 8,626,500 |
| Trotting | 176 | 9.022 | 1,587.9 | 1 30 | 8,574,660 |
| Total | | | | | 17,201,160 |
| ROAD WORK (RIDER WITH PACK). | | | | | |
| Walking | 265 | 5.446 | 1,443.2 | 1 30 | 7,793,280 |
| Trotting | 265 | 9.022 | 2,390.8 | 1 30 | 12,910,320 |
| Total | | | | | 20,703,600 |
| MILITARY MANEUVERS (RIDER WITH LIGHT PACK). | | | | | |
| Walking | 198 | 5.446 | 1,078.3 | 2 00 | 7,762,760 |
| Trotting | 198 | 9.022 | 1,786.4 | 3 00 | 19,293,120 |
| Total | | | | | 27,055,880 |

According to the calculation of an English army officer, the mean ratio of carrying power to body weight is 1:5.757; that is to say, it takes, roughly speaking, 5.75 pounds of body weight to carry 1 pound on the back during severe exertion (racing excepted). The rule he gives for ascertaining the carrying power of a horse is to divide his body weight by 5.757, and if intended for only moderate work to add to the product 28 pounds. It has to be noted that the observations on which this rule is based were made upon military horses. It is doubtful if it would work out so accurately if applied to all horses used for the saddle.

**MUSCULAR WORK IN ITS RELATION TO THE RATION.**

Many experiments have been made, chiefly in Europe, to determine the exact relation between the amount of muscular work performed and the amount of the different nutrients required per day. It is the

opinion of many prominent investigators that, provided a sufficient amount of protein is supplied for physiological maintenance, i. e., to replace the wear and tear of body tissue, it is immaterial which of the three classes of nutrients (protein, fat, and carbohydrates) furnishes the energy necessary for external muscular work performed by horses.

A view very commonly held to-day is much the same and in accord with the above, viz, that provided an adequate quantity of protein and energy are available for maintenance, it is theoretically immaterial which class of nutrients furnish the energy for muscular work, although carbohydrates and fat are practically better suited for this purpose than protein, since any great excess of the latter is costly and may prove injurious to the health. In this case the term maintenance is not used in its strict physiological sense, but refers to a condition in which no appreciable amount of external muscular work is performed, and in which the internal muscular work is fairly uniform from day to day and the body weight practically constant.

The speed at which the horse travels, the way in which the load is distributed, the external temperature, and other conditions evidently have an effect upon the work performed, increased speed, increased temperature, and faulty distribution of the load increasing the work.

It is commonly recognized that when work is increased more feed is required. Many experiments have shown that the pace at which work is done also has an effect, and in general the greater the speed the larger the feed requirement. Some of the reasons given for the fact that rapid work is less economical than slow work are the increased action of the heart when the horse is trotting or galloping; the lifting of his own weight at each step only to allow it to fall again, thus developing heat; and the increase of body temperature with exertion and the loss of heat by the evaporation of water through the skin and lungs.

A number of investigators have studied the relation between muscular work and digestibility. Small variations have been observed under the different experimental conditions, the feed being on an average a little less thoroughly digested when severe work was performed. But on the whole it seems fair to say that from a practical standpoint the diminished digestibility due to muscular work is not very important.

A recent German investigator found that the amount of food required was affected by anything that disturbed the horse. In one experiment a horse confined in a stable was much disturbed by flies and consequently restless. The increased work in fighting the flies caused an increase of 10 per cent of the carbon dioxid excreted. This means that more food material was burned in the body than was the case when the horse was quiet, for the combustion of food in the body, it will be remembered, furnishes the carbon dioxid excreted in the breath.

In addition to other matters, this same investigator noted that the body conformation had a marked effect on the economical production of work. He found that defects in external conformation and movements necessitate an increased amount of muscular exertion. This has an important bearing upon the market value of the horses. Too low a stall temperature also increases the amount of material required for maintenance. In many cases observed this increase was hardly covered by 2 pounds of oats daily.

## PROPORTION OF ENERGY OF FOOD EXPENDED FOR INTERNAL AND EXTERNAL MUSCULAR WORK.

A horse converts 38.3 per cent of the energy of food into mechanical work. On account of the energy required for respiration, the beating of the heart, etc., only about 34 per cent of the energy of the food is actually available for external muscular work. The best record for a steam engine is said to be an efficiency per indicated horsepower of 22.7 per cent on the basis of total heat supply. Per delivered horsepower the amount is probably 10 per cent less. The animal is, therefore, seen to be a much more efficient machine than the engine.

## ENERGY REQUIRED TO CHEW AND DIGEST FOOD.

One of the most interesting of the lines of investigation followed in an extended series of experiments, carried on under the direction of Professor Zuntz at the Agricultural High School in Berlin, was the determination of the energy required to chew and digest different foods. The experiments were complicated and too extended to describe here except in very general terms. They showed that the respiratory quotient, i. e., the ratio of the carbon dioxid excreted in the breath to the oxygen consumed from the air is a very delicate index of the changes which take place in the body. It was found that the internal muscular work expended in chewing, swallowing, and digesting food could be determined by the variations in the respiratory quotient and in the amount of carbon dioxid excreted when this kind of work was performed, as compared with the amount when the animal rested. Different feeding stuffs modified the respiratory quotient in different ways, and it was evident that some required more labor for digestion and assimilation than others. This is a matter of considerable importance, for it is evident that if two feeding stuffs of practically the same composition are digested with equal thoroughness but one requires for digestion and assimilation the expenditure of more internal muscular work than the other, it is really less valuable; in other words, the two may contain the same amount of digestible nutrients, but one causes the body more labor to assimilate than the other. On the basis of Zuntz's average figures of composition and digestibility, 1 pound of hay furnishes 0.391 pound of total nutri-

ents, and 1 pound of oats 0.615 pound of nutrients. As regards nutritive value, hay and oats are therefore commonly said to be to each other as 400 : 600. As shown by the experiments referred to, 0.123 pound, or 20 per cent of the total nutritive material present in 1 pound of oats is expended in the labor of chewing and digesting them. In the case of 1 pound of hay, 0.192 pound, or 49 per cent of the total nutritive material, is required for the same purpose. Therefore hay and oats stand really in the proportion of 200 : 490. In other words, oats surpass hay in feeding value two and one-half times instead of one-half time, as they are ordinarily assumed to do.

## "TRUE NUTRITIVE VALUE" OF FEEDING STUFFS.

Taking into account the internal muscular work required to chew and digest foods and deducting this from the digestible nutrients present in the foods, what we may call the "true nutritive value" of a number of feeding stuffs was calculated by Zuntz with special reference to horses. The results are shown in the following table:

TABLE 4.—*Calculated "true nutritive value" of 1 pound of different feeding stuffs.*

| Feeding stuffs. | Dry matter. | Crude fiber. | Total digestible nutrients.[a] | Labor expended in chewing and digestion. | | True nutritive value. | |
|---|---|---|---|---|---|---|---|
| | | | | In terms of energy. | In terms of nutrients.[a] | In terms of energy. | In terms of nutrients.[a] |
| | *Per cent.* | *Pound.* | *Pound.* | *Calories.* | *Pound.* | *Calories.* | *Pound.* |
| Meadow hay (average quality) | 85 | 0.260 | 0.391 | 376 | 0.209 | 328 | 0.182 |
| Alfalfa hay cut at beginning of bloom | 84 | .266 | .453 | 394 | .219 | 422 | .234 |
| Red-clover hay | 84 | .302 | .407 | 429 | .239 | 303 | .168 |
| Winter-wheat straw | 86 | .420 | .181 | 535 | .297 | −209 | −.116 |
| Oats (medium quality) | 87 | .103 | .615 | 224 | .124 | 883 | .491 |
| Maize | 87 | .017 | .785 | 148 | .082 | 1,265 | .703 |
| Field beans | 86 | .069 | .720 | 200 | .111 | 1,096 | .609 |
| Peas | 86 | .059 | .687 | 183 | .102 | 1,054 | .586 |
| Air-dry disembittered lupines. | 86 | .157 | .645 | 294 | .163 | 867 | .482 |
| Linseed cake | 88 | .094 | .690 | 225 | .125 | 1,018 | .565 |
| Potatoes | 25 | .010 | .226 | 49 | .027 | 358 | .199 |
| Carrots | 15 | .016 | .113 | 37 | .021 | 166 | .092 |

[a] Protein, plus carbohydrates, plus crude fiber, plus fat multiplied by 2.4.

As will be seen, the true nutritive value of straw is negative in the above table. In this connection it was stated that so long as heat alone is considered, the digestible nutrients in straw should be given their full value as shown by the heat of combustion. Providing the labor of digesting a mixed ration does not exceed 4.63 pounds, or 8,316 calories, the digestible nutrients in straw have a positive value. If the labor of digestion is greater than this, an excess of straw would only increase the internal muscular work, so that approximately a quarter of a pound of nutrients per pound is of no value for the body.

## FIXING RATIONS ON THE BASIS OF INTERNAL AND EXTERNAL MUSCULAR WORK.

It was shown in connection with the above tests that a ration suited to the performance of any kind of work can be calculated on the basis of the nutritive material and energy required for maintenance plus that needed for the work performed, though the method is too involved to discuss in detail. Thus on the basis of experiments and observations it was calculated that a horse weighing 1,100 pounds requires for maintenance 7.056 pounds of true available nutrients. Similar calculations were made for a horse working with or without harness and wagon on a level and going up or down an incline at different gaits.

It was found that the amount of total nutrients required increases with the increased speed; furthermore, a greater amount is required in climbing an incline than for forward progression on a level. In descending a gentle incline a much smaller amount of nutrients is required than in climbing the same incline, and as compared with the motion of forward progression there is also a saving in the amount of nutrients needed. In general, it was found that the energy expended was less than in traveling on a level, provided the incline was less than 5° 45′. At this point it was equal to the amount expended in traveling on a level. If the incline was greater, energy was required to keep the body from descending too rapidly and the expenditure was greater than on a level.

## SUMMARY.

Some of the principal deductions noted in this bulletin follow; the conclusions which have been drawn for horses applying with equal force to other animals of the same group, such as asses and mules.

Horses, like other animals, require a definite amount of nutrients and energy per 1,000 pounds live weight for maintenance, and an extra amount, chiefly energy-yielding nutrients, for muscular work, the amount being proportional to the character and amount of work performed.

The amount of nutrients required increases with the amount of work done and with increased speed. More energy is required for climbing an incline than for traveling on a level. In descending an incline of less than 5° 45′ less energy is required than in traveling on a level. If the incline is greater than 5° 45′, more energy is expended (to prevent too rapid descent) than in walking on a level.

The ration should consist of concentrated and coarse feeds. The ratio by weight of coarse fodder or bulky feed to concentrated feed in the ordinary ration has been found to be about 1:1. Crude fiber may perhaps be fairly considered as the characteristic constituent of coarse fodder. The ratio of crude fiber to protein in the average of a large number of American rations has been found to be about 2:1.

Theoretically at least any sufficient and rational mixture of wholesome grains, by-products, roots, and forage crops, green and cured, may be used to make up a ration, though there is a very general prejudice in favor of oats and hay, corn and hay or corn fodder, and barley and hay (frequently that made from cereal grains), the first-named ration being perhaps that most commonly regarded as satisfactory for horses. A corn ration is very commonly fed in the middle West and Southern United States—that is, in the corn-producing belt. The barley ration is quite characteristic of the Pacific coast region. In the semiarid regions of the United States Kafir corn and alfalfa have proved to be of great value, owing to their drought-resisting qualities. Both crops have been found useful for horse feeding. Of the two alfalfa has been used much more commonly, and has given very satisfactory results.

Investigations have shown that it is often best to modify a ration, for instance, by substituting corn wholly or in part for oats, so that while the horses remain in good condtion, the cost of the ration is diminished. Where large numbers of horses are fed this is often a matter of considerable importance.

Generally speaking, horses digest their feed, and especially the nitrogen-free extract and crude fiber in it, less thoroughly than ruminants.

Horses require a considerable amount of water daily, the quantity varying with different seasons of the year, the amount of work performed, etc. The time of watering, whether before or after feeding, is a matter of little importance, and, generally speaking, may be regulated to suit the convenience of the feeder. Horses become used to either method of watering, and irregularity should be avoided, as sudden changes are apt to prove disturbing.

Judging by the average results, representing the practice of a large number of successful American feeders, and also the results of many tests at the experiment stations in different parts of the United States, horses with light work consume on an average a ration furnishing per day 0.99 pound of digestible protein and 14,890 calories of energy per 1,000 pounds live weight. Similar values for horses at moderate work are 1.49 pounds digestible protein and 22,710 calories. It is believed that for horses at severe work larger amounts are required. Generally speaking, these average values are less than those called for by the commonly accepted German feeding standards for horses performing the same amount of work, yet from what is known regarding the American horses it seems fair to say that they were well fed.

Additional experiments are much needed which will result in a series of standards suited to American conditions.

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